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RESEARCH PAPER

Modeling Forest Owner Harvesting Behaviour and Future Intentions in Tasmania

Ingrid van Putten · Sarah Jennings

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Abstract Our ability to design public policies that effectively promote the efficient use of privately owned forest resources is underpinned by an understanding of the way in which forest production and investment decisions are made, and of how forest owners respond to changes in social, economic, and institutional conditions. A model of non-industrial private forest owners (NIPF) past harvesting behaviour and future harvesting intentions using a logit approach is presented. A Tobit model, which investigates harvesting intensity, is also developed. The responses to a survey of 386 NIPF owners in Tasmania are used to construct the data set consisting of socio-economic characteristics of NIPF owners, their forest ownership objectives, and property characteristics. The current study is innovative in that the role of NIPF owner objectives and attitudes is assessed in three econometric models exploring past harvesting behaviour, harvesting intensity, and future harvesting intentions. A series of observations can be made from comparing the results of the three models. For example, higher pulp prices are unlikely to affect NIPF owners harvesting intentions but are likely to increase harvesting intensity. The financial characteristics of the NIPF owner contribute most to predicting future harvesting intentions, with financial security being a disincentive to future harvesting. Landowner objectives and attitudes are important in explaining past harvesting activities and future intentions but do not significantly affect harvesting intensity. Furthermore, there are significant differences between different types of landowners in terms of the incentives that are likely to make them change their mind about participating in native forest harvesting.

I. van Putten (✉)
Marine and Atmospheric Research, CSIRO, GPO Box 1583, Hobart, TAS 7001, Australia
e-mail: ingrid.vanputten@csiro.au

S. Jennings
School of Economics and Finance, University of Tasmania, Hobart, TAS, Australia

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Introduction

Non-industrial private forest (NIPF) owners own approximately 11 million hectares of native forest in Australia. In Tasmania alone, an estimated 28 percent of the State's total native forest resource is on private land (Private Forests Tasmania 2008). Privately owned forests provided for approximately 42.5 percent of total timber production Tasmania in 2007–2008 (Private Forests Tasmania 2008). Additional to privately owned native forest, private land plantations supply increasing quantities of timber. Areas of hardwood plantations increased from 44,000 hectares in 1998 to over 171,980 hectares in 2008 (Private Forests Tasmania 2008). The "overwhelming majority" of the timber supply in Tasmania was pulpwood (Private Forests Tasmania 2002; Private Forests Tasmania 2008).

Notwithstanding the role of NIPF owners, their contribution to overall timber supply is largely uncertain in Tasmania and elsewhere. For this reason, numerous studies have investigated the variables that affect private landowners' timber supply internationally (e.g. Binkley 1981; Gramann et al. 1985; Jamnick and Beckett 1988; Salkie et al. 1995; Jennings and Matysek 1999). A comprehensive review of econometric studies of NIPF owners was undertaken by Beach et al. (2005). In this study the variables that affect harvesting behaviour were divided into four categories: market drivers; policy variables; owner characteristics; and plot/resource conditions.

Wear and Parks (1994) showed empirically that the characteristics of forest owners had a significant impact on forest management and harvesting decisions. Other studies that also focussed on predicting NIPF owner harvesting intentions on the basis of owner characteristics (Binkley 1981; Jamnick and Beckett 1988; Clements and Jamnick 1989; Wear and Parks 1994; Salkie et al. 1995) found that, for instance, being a younger farmer, shorter length of property ownership, and higher education levels increased the probability harvesting. The NIPF owner's attitude and beliefs were also frequently found to affect harvesting behaviour (e.g. Kurtz and Lewis 1981; Marty et al. 1988; Karppinen 1997). Gramann et al. (1985) found that experience positively affected future harvesting intentions.

Property characteristics, such as owning a large forest area (e.g. Green and Blanter 1986; Bolkesjø and Baardsen 2002) and having undertaken forest management activities and plans (Loikkanen et al. 1986; Jamnick and Beckett 1988; Løyland et al. 1995; Wellstead et al. 1999), were also associated with greater harvesting intentions. Similarly, lower private landowner income levels positively affected forest harvest decisions (Binkley 1981; Kuuluvainen et al. 1996). Moreover, the probability of harvesting was reduced if the landowner earned off farm income (Dennis 1989; Løyland et al. 1995). As well as landowner characteristics and attitudes, and property characteristics, timber prices also played a role in the harvesting decision (Binkley 1981; Adams and Haynes 1989; Adams et al. 1991; Hetemäki and Kuuluvainen 1992; Kuuluvainen et al. 1996). The effect

of increased stumpage prices on increased harvesting intentions was determined by Messmer et al. (1995), Løyland et al. (1995) and Bolkesjø and Baardsen (2002).

The studies that have investigated NIPF harvesting behaviour have mainly been undertaken in the USA (e.g. Binkley 1981; Dennis 1989, 1990), Canada (e.g. Clements and Jamnick 1989; Salkie et al. 1995; Wellstead et al. 1999), and Scandinavia (e.g. Kuuluvainen and Salo 1991; Løyland et al. 1995; Kuuluvainen et al. 1996). In Tasmania, behaviour of North West Tasmanian NIPF owners was investigated in a preliminary study by Jennings and van Putten (2001). The marginal timber harvest and tree planting probabilities for this region were estimated. While the results of that study confirmed the importance of a number of property and NIPF owner related variables, generally consistent with the results of the other comparable studies, the data set included no economic or attitudinal variables.

This current study, in which econometric models of Tasmanian NIPF owner's past harvesting behaviour, future harvesting intentions, and timber harvesting intensity are developed, is the only such study in Australia in general and in Tasmania in particular. The majority of NIPF behavioural studies have been undertaken in the northern hemisphere where the political environment related to native forestry issues may be different from that observed in Tasmania where debate remains polarised. This study contributes to a better understanding of the behavioural drivers of NIPF owners, who have been exposed to the politically divisive native forest harvesting issue, by incorporating NIPF ownership objectives and a self-assessment of the strength of their behavioural intentions.

The rest of this paper proceeds as follows. Section 2 provides an overview of the theoretical background and econometric modelling techniques used to analyse individual harvest and forest management behaviour. The survey and data set upon which the empirical analysis is based are described in Sect. 3. This includes a brief description of the price data and the method used to construct a variable for landowner objectives. Results are presented in Sect. 4 and discussed in the final Section.

Theoretical Context and Econometric Modelling Method

The theoretical models that form the basis of normative assessments of timber supply generally conform to the profit (rent) maximisation paradigm (Hyde 1980) or the household utility maximisation framework (Max and Lehman 1988). A strict profit maximising framework fails to encompass other objectives a landowner may have for their land. On the other hand, the utility maximisation framework can accommodate non financial benefits that may result from land ownership. Utility can explain economic behaviour in terms of individuals aiming to increase, or maximise their utility. The utility maximisation framework is applied in this current research.

It is theorised that the NIPF owner seeks to maximise utility with respect to their forested land. The utility derived from the choice to harvest or not is based on the attributes of the choice, which are specific to the individual decision maker. The NIPF owner aims to maximise utility where utility depends on a vector of timber

stand and property attributes as well as socio-economic characteristics of the individual, such as owner income, and the owners preference for non-timber benefits.

The utility function includes non-timber amenity services and other forest constraints that bind the decision (Kuuluvainen et al. 1996). Following Binkley (1981) the utility function is defined over r and y (Eq. 1):

$$\max U(r, y) \tag{1}$$

$$y = y^e + p^t t - \mathrm{cl} \tag{2}$$

$$r = g(t, l) \tag{3}$$

where y is net income, y^e is income exogenous to the model, P is the price of timber and t is the amount of timber cut. The cost of holding land is signified by c and l is the amount of land held. The non-timber output and consumption is shown by r and related to the timber and non-timber land output by $g(t,l)$. Substituting Eqs. 2 and 3 into 1 and differentiating yields Eq. 4.

$$u_y p^t = -u_t g_t \tag{4}$$

"The marginal value of an additional unit of timber output equals the marginal value of the non-timber outputs which must be foregone to obtain that unit" (Binkley 1981, p. 33). The indirect utility function shown in Eq. 4 can be used in a stochastic utility model of choice (Binkley 1981, p. 42). The utility of the choice alternatives (i which run from 1–n) depend on the characteristics of the alternative and those of the NIPF owner (k). The NIPF owner will choose alternative i only if the utility for i is greater than that for the other alternatives.

$$U^k(x^i) = V^k(x^i) + \varepsilon^i \tag{5}$$

where ε^i is the error term. If the error term has a Weibull distribution (McFadden 1974), then the probability of NIPF owner k choosing alternative j follows a logistic distribution and is given by:

$$P_j^k = \frac{\exp[V^k(x^j)]}{\exp[V^k(x^i)]}. \tag{6}$$

The binary logit model achieves non-linearity and restricts predicted probabilities to fall between zero and one by using an S-shaped cumulative density function (CDF) to transform the dichotomous 0–1 dependent variable. In the case of the logit model the transformation uses the cumulative logistic probability function and is specified as

$$P_i = \frac{1}{1 + e^{-Z_i}} \tag{7}$$

where e is the base of natural logarithms and $Z_i = \alpha + \beta X$, a and β are the estimated parameters of the logit model and X is a vector of explanatory variables. The regression equation estimated in logit analysis is derived after simple manipulation of Eq. (7) where the dependent variable in the regression equation is the natural logarithm of the odds that a particular choice will be made and the

right hand side of the regression is linear in the parameters of the model. When only one or a few observations on each decision-maker are available, estimation of the parameters of the logit model must be done using the maximum likelihood estimation procedure. The maximum likelihood procedure has a number of desirable properties. All parameter estimates will be consistent and efficient asymptotically. In addition, all parameter estimates are asymptotically normal, so that a t test of parameter significance can be applied. Tests of the significance of all, or a subset, of the coefficients can be performed using the likelihood ratio (LR) test.

Estimated coefficients do not indicate the increase in the probability of the event occurring, given a one-unit increase in the value of the independent variable. Rather, these coefficients reflect the effect of a change in an independent variable on $\ln[P_i/(1-P_i)]$ or the log of odds. The marginal probability effects for the logit model are derived as follows

$$\frac{\partial P_i}{\partial X_{ij}} = \frac{\beta_j \times e^{Z_i}}{(1+e^{Z_i})^2} \tag{8}$$

where j denotes a particular independent variable. Given the non-linearity of the logit model specified in Eq. (7), the marginal effects will depend on the original probability and the values of all other independent variables and their coefficients.

Tobit models investigate NIPF owner and property characteristics, and NIPF owner attitudes and the simultaneous decision on how much to harvest (Wear and Parks 1994). The tobit model was first formulated by Tobin (1958). In this current study the observed harvest (the dependent variable) has to be non-negative. The data are thus censored at zero where no harvesting has taken place. This leaves a total of 70 observations for the tobit analysis. Even though the number of observations is low, statistical indicators for the model, reported in the next Section, indicate that the model is stable and reliable.

Harvesting intensity is a linear function of the independent variables. Following Bolkesjø and Baardsen (2002) the regression model is given by:

$$T_{\mathrm{ks}} = T^*_{\mathrm{ks}} = X_{\mathrm{ks}}\beta + \varepsilon_{\mathrm{ks}} \quad \text{if the right hand side } > 0$$
$$T_{\mathrm{ks}} > 0 \quad \text{otherwise} = 0(9)$$

T^*_{ks} is the harvesting intensity. T_{ks} is the actual harvest of owner k in year s (s = 1, 2, 3). Where β is the coefficient vector and $\varepsilon_{\mathrm{ks}}$ is the normally and independently distributed error term with mean zero and constant variance (Maddala 1983). The vector of exogenous variables is defined in Table 2 of this report.

Forest Owner Intention Survey

In a Forest Owner Intention Survey (FOIS) carried out in Tasmania in October 2001, data was collected pertaining to NIPF owner characteristics, their attitudes and objectives, property characteristics, and forest harvesting activities. The data is used to develop three models: past harvesting activity (PASTHARV), future harvesting intentions (FUTHARV), and harvesting intensity (PULPHARV).

The general aim of the FOIS survey was to better understand NIPF owner intentions in relation to forestry activities. A survey of this type is conducted approximately every 5 years by Private Forests Tasmania (PFT) for reporting requirements to the National Forest Inventory and estimating NIPF timber availability. For the purpose of this current research, additional questions were incorporated in the 2001 FOIS. These specific questions were not asked in more recent FOIS surveys.

A survey sample of 2,000 was obtained using ARCVIEW random sampling extension (Personal communication Mr. P. Donnelly, Private Forests Tasmania 2002) based on two geographic data sets, the Tasmanian tenure boundaries, and forest cover and forest class information.[1] A total of 1,973 sample points was located and ownership details identified. The final sample consisted of 1,664 property owners, 188 of whom owned properties containing multiple sample points. Following pre-testing, the survey was mailed out and no follow-up procedures were implemented due to financial constraints. Useable surveys for 598 sample points were returned, corresponding to a response rate of 32% for sample points. A 30% response rate for property owners was achieved (as some properties contained multiple sample points). The response rate is consistent with that of other landowner surveys in Tasmania (Jennings and van Putten 2001, 2006; Putten van 2008). Survey responses with incomplete answers were excluded (96 of the original FOIS responses) leaving a sample size of 386. *t*-tests of differences in sample means and proportions were used to establish whether there was a difference between respondents who were included and those who were excluded from the analysis. Significant differences were found for only three of more than 30 variables and indicated that members of the excluded group owned larger properties and were more likely to be male and less likely to have attained a university education than those included.

Survey respondents were asked to complete 48 questions in three separate sections. Section 1 was aimed at establishing general property characteristics, past logging and management activities, and future logging intentions. Section 2 of the survey explored forestry activity undertaken in the past 3 years on a particular tract of forested land which was identified on a map attached to the survey. Section 3 obtained personal information, such as gender, age, income and educational status. The respondent's objectives for forest ownership were also explored in this section. The responses to Sects. 1 and 3 form the basis for two binary choice harvesting models developed in this research. A harvesting intensity model is developed for survey respondents who reported having harvested timber.

Seventy respondents with positive harvesting activities indicated they had harvested pulpwood while 55 indicated harvesting sawlogs. Thirty respondents indicated they supplied firewood only. Fifty NIPF owners had harvested both pulpwood *and* sawlogs. Only 9 respondents indicated they had harvested every year in the past 3 years. Thirty-one respondents indicated they had harvested in only one

[1] There are approximately 4,000 landowners in Tasmania listed on the database used to extract the random sample.

Table 1 Reported prices for pulpwood and sawlogs between 1998 and 2000

	Average price ($/tonne pulp; $/m^3 sawlogs)	Price range ($/tonne pulp; $/m^3 sawlogs)	Average area (ha)
2000 pulp*	$10.21	$2–$20	5,983
1999 pulp	$11.89	$8–$20	7,167
1998 pulp	$11.49	$8–$20	8,763
2000 sawlog*	$24.36	$10–$50	520
1999 sawlog	$24.10	$12–$32	456
1998 sawlog	$23.52	$13 $32	550

* Volume figures are derived from the midpoint in the ranges available for selection in the FOIS

of the 3 years. Table 1 shows the reported average pulp and sawlog prices and the size of the harvested area for 3 years.[2]

As expected, and in line with Tasmanian forestry activities as reported by government sources (Private Forests Tasmania 2002), larger areas were dedicated to the production of pulpwood than sawlogs. The average prices as reported by survey respondents were comparable to the officially reported prices of $12 per tonne for those years (Private Forests Tasmania 2002). Some regional differences in average reported prices were observed, with average pulp and sawlog prices somewhat higher in the North/North-West for all 3 years.

Tasmanian NIPF Owner Types

NIPF ownership objectives and attitudes were also explored in the FOIS survey. It was hypothesised that NIPF owner's attitudes and objectives contribute to explaining past harvesting behaviour and future harvesting intentions. Typologies of NIPF owners based on the similarities of their stated forest ownership objectives and attitudes have been developed in other studies (e.g. Jennings and van Putten 2006; Ní Dhubháin et al. 2007). These NIPF owner typologies have also been incorporated in econometric models and used to explain harvesting behaviour (e.g. Kuuluvainen et al. 1996; Karppinen 1998).

The NIPF owner typology used in this current study is based on the rating scores according to importance, using a five-point Likert scale ('*not important*' to '*very important*'), of 18 forest ownership attitudes and objectives. The wording of the question was 'How important are each of the following objectives of forest ownership to you?' The list of ownership attitudes and objectives was adapted from Kuuluvainen et al. (1996) to suit Tasmanian circumstances. The list included a range of monetary, environmental, recreational, emotional, aesthetic, agricultural and other land management objectives. The 18 variables describing forest ownership objectives were condensed using principal component analysis (PCA) and rotated using the VARIMAX method to form a reduced number of interpretable variables (following Kaiser 1958; Mulaik 1972).

[2] All prices are reported in Australian dollars.

Four NIPF owner groups were identified: *income and investment owners* (116 respondents); *non-timber output owner* (111 respondents); *agriculturalists* (102 respondents); and *multi objective owners* (57 respondents; Jennings and van Putten 2006). The rating list did not focus on objectives related to forest harvesting and, as such, the typologies are not created on the basis of ownership characteristics. The NIPF owner groups identified in Jennings and van Putten (2006) were broadly comparable to those identified in other studies (e.g. Kurtz and Lewis 1981; Karppinen 1998; Kline et al. 2000). These landowner types were used as explanatory variables in three econometric models.

Modeling Results

In this section three models are estimated that investigate forest harvesting behaviour by NIPF owners in Tasmania. The first model, the PASTHARV model, uses the binary response to the question in which respondents were asked to indicate if any timber had been harvested for commercial purposes from their property in the past 3 years. The dependent binary variable for the FUTHARV is based on the question if NIPF owners intended to harvest for commercial timber production in the next 3 years. The PULPHARV is based on the reported past pulpwood harvesting activities. The volume data is used as the dependent variable in the PULPHARV with price included as one of the independent variables.

Due to the low number of observations greater than zero for sawlog harvesting, this tobit model was perceived to be of insufficient stability to provide insight into sawlog harvesting intensity. Consequently only pulpwood harvesting is considered in this current study.

The models are estimated using two statistical estimation methods, the logit approach, where the dependent variable is binary, and the tobit approach, where the dependent variable is non-zero and continuous. Loikkanen et al. (1986) describes these models as the sale probability (logit) and joint decisions (tobit) models. The choice of independent variables was based on expectations and a review of the literature (reported above). The sample means for all variables used to estimate the three models are shown in Table 2.

As multi-collinearity is commonly found in non-experimental data, the correlation coefficients between all variables were determined. Highly collinear variables cause regression parameters to be inefficient and can cause the signs of the regression coefficient to be counter-intuitive (Gujarati 1988). No Pearsons correlations greater than 0.5 were found. Variables with correlation coefficients between 0.3 and 0.5 were not excluded from the analysis as the results were sufficiently robust to justify their inclusion. Logarithmic transformations of variables are appropriate to achieve symmetry in the central distribution (Cohen 1969). Where either the skewness and kurtosis values were outside the minus three and three range, the log of the variable was taken.

The binary regression option and forward conditional analysis in SPSS for windows (version 11.0.0) was used to estimate the PASTHARV and FUTHARV models. Stepwise variable entry examines the variables in the block at each step for

Table 2 Variables used in the PASTHARV, FUTHARV, and PULPHARV models for NIPF owners in Tasmania

	Description	Coding	Sample mean**	SD
NIPF owner characteristics				
AGEL45	NIPF owner is less than 45 years of age	1 = yes, 0 = no	0.31	0.465
MALE	NIPF owner is male	1 = yes, 0 = no	0.84	0.363
TIREDU	NIPF has achieved tertiary education or higher	1 = yes, 0 = no	0.52	0.500
YEARSOWN	Number of years the property has been owned by the (direct) family (number)	Cont	20.37	21.867
RESIDE	NIPF owner lives on the property	1 = yes, 0 = no	0.50	0.501
Property characteristics				
AREA	Size of the property (ha)	Cont	960.46	30,414.76
AREATIM	Timbered area on the property (ha)	Cont	437.33	1761.09
OWNPROP	NIPF owner owns the property individually (not as a partnership or private/public company)	1 = yes, 0 = no	0.48	0.500
SELLPROP	NIPF owner intends to sell the property in the future	1 = yes, 0 = no	0.09	0.291
OTHPROP	Another property is owned by the NIPF owner	1 = yes, 0 = no	0.38	0.486
PROPTIM	NIPF owner has harvested timber from other properties owned by them	1 = yes, 0 = no	0.12	0.330
PTR	NIPF owner has Private Timber Reserve on the property	1 = yes, 0 = no	0.18	0.388
GRAZE	The property is mainly used for grazing	1 = yes, 0 = no	0.58	0.494
CONSMAN	NIPF owner has undertaken conservation management activities	1 = yes, 0 = no	0.41	0.492
FORMAN	NIPF owner has undertaken forest management activities	1 = yes, 0 = no	0.45	0.498
Business characteristics				
GFT	Annual gross farm turnover ($'000/annum)	Cont	$146	$260
FORPERC***	The percentage of GFT that is earned from forestry related activities (%)	Cont	0.24	0.290
FINASSIS	NIPF owner received some form of financial assistance to undertake commercial forestry activities	1 = yes, 0 = no	0.04	0.194
NODEBT	NIPF owner has no debts owed on the property	1 = yes, 0 = no	0.60	0.491
OFFINC	NIPF owner earns off farm income	1 = yes, 0 = no	0.64	0.480
PULPPR***	The pulp price ($/tonne)	Cont	11.09	3.203
NIPF owner type****				

Table 2 continued

	Description	Coding	Sample mean**	SD
AGRIC	NIPF owner is typified as *agriculturalist*	1 = yes, 0 = no	0.26	0.442
INVEST	NIPF owner is typified as *income and investment owner*	1 = yes, 0 = no	0.30	0.459
MULTI	NIPF owner is typified as *multi objective owner*	1 = yes, 0 = no	0.15	0.355
NONTIMB	NIPF owner is typified as *non-timber output owner*	1 = yes, 0 = no	0.29	0.453
Dependent variables				
PASTHARV*****	NIPF owner has harvested timber from the property in the past 3 years	1 = yes, 0 = no	0.25	0.433
FUTHARV	NIPF owner intends to harvest their forest for commercial timber production in the next 3 years	1 = yes, 0 = no	0.17	0.377
PULPHARV	Pulp harvested in the past 3 years (tonne/ha)	Cont	7170.89	6249.00

Not all variables were significant in all three models

** Sample means for continuous variables are taken where $x > 0$

*** Average for non zero observations

**** Used as a dummy variable

***** Only used as a dependent variable in the model predicting future harvesting behaviour

entry or removal in the model. Forward stepwise procedure enters the variables in the block one at a time based on entry criteria. All variables must pass the tolerance criterion of 0.0001 to be entered in the equation. A variable is not entered if it causes the tolerance of another variable already in the model to drop below the tolerance criterion (SPSS version 11.0.0). Application of the forward stepwise procedure to the data used in the PASTHARV model results in a reduction in the number of independent variables from 25 to 5.

The coefficients of the model were estimated using the LIMDEP maximum likelihood routine *logit.*[3] The estimated coefficients, standard error, and significance level for the PASTHARV model are reported in Table 3.

The model is highly significant with a P value of 0.000 and chi-square of 63.525. The PASTHARV model correctly predicts 80.1% of the observations. However, the model is better at predicting cases of non-harvest, 283 out of 290 (97.6% correct) than cases of harvesting, 26 out of 96 (27.1% correct).

The sign of the coefficient indicates the direction of the effect of a change in an independent variable on the probability of a NIPF owner having harvested timber in the past. A high gross farm income, having received financial assistance to undertake commercial forestry activities, and having managed the forest timber

[3] LIMDEP was preferred for this routine over SPSS as LIMDEP provides additional marginal probability statistics.

Table 3 Estimated coefficients, standard error and significance level for the PASTHARV model

Variable	Coefficient	Significance level	Standard Error
CONSMAN	−0.646	<0.005	−2.179
FORMAN	+1.545	<0.005	5.348
FINASSIS	+1.153	<0.010	1.899
GFT	+0.00146	<0.005	2.949
NONTIMB	−0.867	<0.005	−2.654
Constant	−1.756	<0.005	−7.729

$P = .0000$

Chi-squared = 63.525

Number of observations = 386

Log likelihood function = −184.7480

Restricted log likelihood = −216.5103

Table 4 Marginal probability effect for the PASTHARV model

Variable	Change in mean probability	Significance level
CONSMAN	−0.107	<0.005
FORMAN	0.257	<0.005
FINASSIS	0.192	<0.010
GFT	0.000242	<0.005
NONTIMB	−0.144	<0.005

production increases the likelihood of a NIPF owner having harvested in the past. Being a *non-timber output owner* type and having managed the forest for conservation purposes reduces the likelihood of the NIPF owner having harvested in the past.

The non-linear relationship between the dependent and independent variable means that the marginal probability effect will vary with the magnitude of all remaining independent variables. The marginal probability effects for the PASTHARV model are reported in Table 4.

Table 4 shows the effect of a change in the probability of having harvested forest in the past 3 years for a one-at-a-time change in the independent variables, computed at the mean value of the remaining independent variables. For example, an individual who has undertaken conservation management activities on their property is 10.7% less likely to have harvested timber from that property than an individual who has not undertaken conservation management activities, *ceteris paribus*. As can be observed from Table 4, the likelihood of having harvested timber from the property is increased most (25.7%) by having undertaken forest management activities in the past. The magnitude of the effect of gross farm turnover seems small. A $10,000 increase in gross farm turnover increases the likelihood of having harvested timber from the property by 0.2%.

Similar to the PASTHARV model, future harvesting intentions for the next 3 years can be predicted on the basis of a number of property and owner

Table 5 Marginal probability effect for the FUTHARV model

Variable	Change in mean probability	Significance level
PASTHARV	0.1923	<0.005
PTR	0.0522	<0.005
PROPTIM	0.0828	<0.005
YEARSOWN	0.0012	<0.005
NODEBT	−0.0839	<0.005
NONTIMB	−0.0925	<0.005
OFFINC	−0.0641	<0.005
GFT	0.000142	<0.005
AREATIM	0.00104	<0.005

characteristics. Overall, survey responses indicated that the majority of the NIPF owners had no intentions of harvesting their forest in the next 3 years. Other intention surveys in Tasmania also found that a proportion of NIPF owners had no harvesting intentions. For instance the FOIS conducted in 1982 revealed that 33% of the private native eucalypt forest resource was owned by NIPF owners who said they would never sell their timber (Carpenter 1985). The FOIS of 1996 showed that around 40% of native NIPF owners did not intend at that time to participate in the commercial timber market.

In this current study only 17% of NIPF owners indicated they had timber harvesting intentions. This is considerable lower than the two previous FOIS survey cited above. The reason for the increase in non-participation is unclear and additional research will need to be carried out to investigate any socio-economic changes that may underlie this variation.

The FUTHARV model presented below provides information about the variables that contribute to the harvesting decision. The method used to estimate the FUTHARV model is the same as that for the PASTHARV model. For ease of presentation only the marginal probability effects are reported here. The model is highly significant ($P = 0.000$ and chi-square is 90.632) and 9 variables explain future harvesting intentions. The FUTHARV model correctly predicts 85.2% of the observations. The model was better at predicting cases of no harvesting intentions, 307 out of 320 (95.9% correct), than predicting positive harvesting intentions (33.3% correct).

The results for the FUTHARV model indicate that a larger timber inventory, past harvesting activities, ownership of another property where timber has been harvested in the past, longer ownership of the property, and the presence of a Private Timber Reserve (PTR)[4] will increase the likelihood of a NIPF owner harvesting in the future (Table 5). A debt free status, a high gross farm income, being a *non-timber output owner*, and receiving off farm income will reduce the likelihood of the NIPF owner harvesting timber in the future.

The variables that significantly affect harvesting intentions as determined in this current research are similar to those presented in Jennings and van Putten (2001) for

[4] PTRs are a prerequisite tenure related administrative procedure in Tasmania prior to timber harvesting.

Table 6 Incentives that will change the minds of NIPF owners who currently have no harvesting intentions

	Income & Investment owner (n = 116)	Non-timber output owner (n = 111)	Agriculturalist (n = 102)	Multi objective owner (n = 57)
No future harvesting intentions	86 (.74)	104 (.94)	81 (.79)	49 (.86)
Nothing will make NIPF owner harvest*	19 (.22)	73 (.70)	41 (.51)	19 (.39)
NIPF will harvest if financial need arises*	25 (.29)	17 (.16)	27 (.33)	14 (.29)
NIPF will harvest if returns improve*	15 (.17)	3 (.03)	8 (.10)	6 (.12)

* Figure in brackets is taken as the proportion individuals of those who have NO harvesting intentions

North West Tasmanian NIPF owners. The North West study also found forest inventory, past harvesting activities, and a PTR on the property significantly affected the probability of having harvesting intentions.

In this current study it was found that overall, only 13% of NIPF owners had future harvesting intentions. However, there were notable differences in harvesting intentions between NIPF owner types (Table 6). For instance, 94% of *non-timber output owners* had no harvesting intentions whereas 74% of *income and investment owners* has no harvesting intentions. The constancy of harvesting intentions has been explored in other studies. Turner et al. (1977) found that only 58% of NIPF owners' intentions not to harvest their timber remained constant over time. The reason forest owners changed their mind was unclear. Gramann et al. (1985) reported highly stable aggregate harvesting intentions over time, underpinning the validity of using forecast of NIPF owner behaviour based on intentions.

With an understanding of the constancy of harvesting intentions as explored in other studies, in this current study NIPF owners were explicitly asked what would make them change their minds about their harvesting intentions. The latter question revealed some clear difference between the landowner types. For instance, more than two-thirds of *non-timber output owners* indicated that nothing would make them change their mind whereas this applied to only 22% of *income and investment owners*.

Furthermore, economic theory suggests that financial need or improved returns will have a positive effect on supply. However, only 19% (0.16 plus 0.03) of *non-timber output owners* indicated that finances or improved returns would make them change their mind about harvesting their forest. This group stated that, due to environmental reason, nothing would change their mind. In contrast, around 40% of *multi-objective owners*, *agriculturalists*, and *income and investment owners* who currently have no harvesting intentions, indicated that they would change their mind about harvesting their native forest for financial reasons and if returns improved.

A harvesting intensity model for respondents who have harvested in the past is estimated next (PULPHARV). FOIS survey respondents reported pulpwood price

Table 7 Estimated coefficients, standard error and significance level for PULPHARV model

Variable	Coefficient	Significance level	Mean	Standard error	Marginal probability Coefficient
Constant	−3,298	<0.005		1625.08	4
AREATIM	+1.545	<0.005	1488	0.2480	1.531
GRAZE	−4,257	<0.005	0.8143	1026.29	4,222
PULPPRICE	+343.76	<0.005	11.06	124.98	340.99
OTHPROP	+1552.91	<0.010	0.5714	920.14	1540.38
PROPTIMB	−4,568	<0.005	0.2286	1105.70	4,531
OWNPROP	+3,065	<0.005	0.3714	834.53	3,041
GFT	+0.900e-02	<0.005	348571	0.00185	0.893E-02
OFFINC	−2,133	<0.005	0.5714	736.09	2,116
TIREDU	−2,973	<0.005	0.5857	845.74	2,949

$P = .0000$

Number of observations = 70

Log likelihood function = −658.5506

Conditional mean at sample point = 108.1278

Scale factor marginal effects = .0277

and harvest data for sawlogs and pulpwood over 3 years. The harvesting intensity model is estimated for pulpwood harvesting (Table 7).

The marginal probability effect shows the estimated change in harvesting intensity and the probability of harvest as a result of a change in an independent variable computed at the mean value of the remaining variables.

Table 7 shows that the signs of the coefficients are mostly consistent with *a priori* expectations as reported in the literature. For instance, higher pulp prices and a larger timber inventory will increase harvesting intensity. An increase in harvested pulp volume is also predicted if the NIPF owner owns another property. Volumes are predicted to fall if the property is mainly used for grazing or the NIPF owner earns off farm income. Timber supply is expected to fall if harvesting has taken place on other properties owned by the NIPF owner (also found by Loikkanen et al. 1986). Volumes are also predicted to fall if the property owner has tertiary education.

The marginal probability coefficients show that a one dollar increase in the price of pulp will result in a 341 tonnes increase in pulpwood harvest per year. Similarly, a 100 hectare increase in area of native forest will increase the intensity of pulp harvest by 153 tonnes. Owning another property will increase the pulp harvest by 1,540 tonnes. On the other hand both having harvested timber on another property and using the property for grazing purposes will decrease the harvesting intensity by over 4,000 tonnes of pulpwood. In contrast to the PASTHAR and FUTHARV models, landowner attitudes and objectives do not significantly contribute to the harvesting intensity decision.

Discussion and Conclusion

Survey responses for 386 NIPF owners in Tasmania were used to estimate two logit models, one describing past harvesting decisions (PASTHARV) and another describing the intention to harvest in the future (FUTHARV). The binary models were better at predicting cases where no harvesting had taken place in the past and no harvesting was planned in the future because less than one-third of respondents had harvested in the past. A third model, a tobit model was estimated for pulp harvesting intensity (PULPHARV) for 70 survey respondents who reported to have harvested pulp in the past 3 years.

Consistent with economic theory and the literature (e.g. Messmer et al. 1995; Løyland et al. 1995; Bolkesjø and Baardsen 2002), higher pulp prices are predicted to increase harvesting intensity. Interestingly, current pulp prices do not significantly contribute to explaining future harvesting intentions. In other words, the current price of pulp is unlikely to affect positive harvesting decisions by NIPF owners, but it will increase harvesting intensity for those NIPF owners who do harvest (also found by Favada et al. 2007). This result may reflect uncertainty in the NIPF owner's perception of the extent to which current price represents expected future price as reviewed by Beach et al. (2005). Although current pulp prices do not reveal information about the NIPF owner's price expectations, additional questions asked in the survey indicate that only a small proportion of NIPF owners indicate they may change their mind about their harvesting decision if the returns from harvesting improve. Moreover, significantly fewer *non-timber output owners*, the group who are less likely to have harvested in the past, are also less likely to be swayed by increased returns.

Gross farm turnover is the only independent variable that explains past harvesting decisions and future harvesting intentions and also has an impact on harvesting intensity. Although the magnitude of the effect was small, higher gross farm turnover increases the likelihood of past harvesting activities and harvesting intensity. In contrast, *lower* levels of gross farm turnover increases the likelihood of having intention to harvest in the future. This is expected as the monetary imperative to harvest in the future increases with lower income levels. Several of the other significant variables that indicate a better financial situation of the landowner, such as low debt levels or being debt free, decrease the likelihood of future harvesting (Kuuluvainen and Tahvonen 1999). Overall these variables suggest that more financially secure NIPF owners have lower harvesting intentions (Størdal et al. 2008). As found by Bolkesjø et al. (2007) the positive effect of wealth may be a sign of credit rationing but it is unlikely to be the only explanation.

Moreover, the likelihood of future harvesting intentions and also harvesting intensity are reduced by higher levels of off farm income suggesting that financial need is a driving factor. Grazing activities on the farm generate an alternative form of income and reduce the likely harvesting intensity. An alternative income source may reduce the financial need to harvest native forest. These results are consistent with the international literature (Binkley 1981, 1993; Dennis 1989; Løyland et al. 1995; Kuuluvainen et al. 1996, Lien et al. 2007; Størdal et al. 2008).

A larger area of native forest on the property increases the likelihood of future harvesting for commercial timber sales and will also increase pulp harvesting

volumes. The finding that size affects harvesting intentions is consistent with findings by Dennis (1989), Wellstead et al. (1999), Messmer et al. (1995), Løyland et al. (1995) and Størdal et al. (2008) who also determined a relationship between timber inventory and harvesting intentions. However, as indicated by Størdal et al. (2008) the relationship between the level of harvesting and property size is not as straightforward.

Jamnick and Beckett (1988), Wellstead et al. (1999) and Jennings and van Putten (2001) concluded that owners who have invested in forest management for wood production are more likely to harvest than owners who have not. This is also true in this current study where having a PTR on the property increases the likelihood of having positive harvesting intentions. This result is inextricably linked to the fact that PTRs are a prerequisite tenure related administrative procedure in Tasmania prior to timber harvesting. The probability of past harvesting is also increased by having undertaken forest management activities, such as for example pruning (as distinct from a PTR). The receipt of financial assistance related to forest management activities is also a good predictor of past harvesting activities. The receipt of financial assistance is not necessarily conditional on forest harvesting taking place. Conservation management actions will decrease the probability of past harvesting activities. Investing in conservation management may be perceived as in conflict with timber harvesting activities.

Specific owner characteristics (such as age and training) do not appear to influence past harvesting behaviour and future harvesting intentions. In other studies a relationship between the environmental attitude of a NIPF owner and the level of education is often significant (e.g. Jennings and van Putten 2001). In this current study there is no relationship between the independent variable capturing NIPF owner objectives (being a *non-timber output owner*) and education and age with a correlation coefficient of less than 0.200. Education is not significant in the two binary models but higher education levels do reduce timber harvesting intensity, with NIPF owners with higher education levels harvesting lower volumes. Higher education possibly gives NIPF owners more potential and opportunity to determine alternative land options for their forested land. Although the effect is small, ownership of a property for a longer period of time will increase the likelihood of future harvesting for commercial timber sales. The security of longer ownership may create the right preconditions for planning for the future.

Past harvesting activities are a good predictor of future harvesting intentions. This was also found by Gramann et al. (1985) and Young and Reichenbach (1987). The NIPF owner may have gained experience and a sense of familiarly with the timber harvesting process reducing the complexity of the administrative and practical issues next time harvesting takes place. In other words, the threshold that needs to be overcome to start a new activity may be reduced. This is also reflected by experience gained from timber harvesting from another property owned by the same NIPF owner which increases the probability of having harvesting intentions for the future.

This study found that there are considerable differences between the variables that explain past harvesting activities, future harvesting intentions, and harvesting intensity. Higher pulp prices are unlikely to affect NIPF owners harvesting

intentions but will increase harvesting intensity. The financial characteristics of NIPF owners seem to contribute most to future harvesting intentions, with financial security being a disincentive to future harvesting. Forest management behaviour is an important predictor for past harvesting activities and both forest management behaviour and having a PTR explain future harvesting intentions. Experience gained from past harvesting activities contributes most to explaining future harvesting intentions. Landowner objectives and attitudes are important in explaining past harvesting activities and future intentions but do not significantly affect harvesting intensity. This study also finds that the chance of increased harvesting will occur mainly if ownership is transferred from a *non-timber output owner* to any of the other NIPF owner type. The relative strength of two important drivers of NIPF timber supply, financial security and landowner attitudes, will determine the type and mix of policy tools needed to change timber supply in Tasmania. When a lack of financial security drives NIPF behaviour, financial incentives are likely to be effective. In contrast, where NIPF attitude is a driver of behaviour, extension is likely to be a more effective policy tool.

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